Novel Directional Solidification Processing of Hypermonotectic Alloys

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Abstract

With the intent of producing uniform composites, solidification processing of hypermonotectic alloys in a microgravity environment began with the 1973 Skylab mission and has since continued in the U.S. as well as internationally. In review, the results of later experiments are essentially no different than the initial (i.e., extremely disappointing). In microgravity, despite minimizing buoyancy forces, gravity *independent* factors cause coalescence and massive segregation of the liquid phases. This results in a highly inhomogeneous and practically useless composite structure.

The current investigation has several scientific objectives which will be realized by conducting a systematic experimental investigation in conjunction with a thorough modeling effort. The theoretical study will develop a semi-quantitative predictive model relating, microstructure to process parameters for the systems investigated experimentally. This will require close interaction with experiment in order to determine more precisely the role of the various dynamic processes induced by ultrasound in these monotectic systems. Experimentally, a number of novel, ground-based, solidification processing techniques which promote uniform phase distributions have been adapted and/or developed and they will be briefly reviewed. Specifically, ongoing experiments that apply ultrasound with the intent of promoting, suspending and maintaining separation of fine Liquid II droplets which precipitate from the bulk once the temperature drops below the miscibility gap boundary are presented.

The use of ultrasonics during solidification processing is not a recent concept. In 1929 Richards^[1] used lower intensities of sound and was able to emulsify many liquid immiscibility systems. Schmid et al.^[2] (late 1930's) produced a dispersion of lead in the immiscible aluminumlead system that was considerably finer at the top. A number of papers reporting the results of applying ultrasonic energy to solidifying melts have since been published [e.g., reference 3, review paper]; again overall finer and more uniform microstructures resulted. Clancy et al., realizing the need for a uniform distribution of droplets and/or particles prior to solidification processing in a microgravity environment, developed an ultrasonic mixing system for use with Spacelab furnace hardware.^[4] Subsequently, their microstructural examination of a hypermonotectic zinc - 5 and 15 wt pct lead alloys, that solidified in a microgravity environment provided by sounding rockets, showed a better distribution of the Pb-phase with acoustics applied than without.^[5,6] In a similar microgravity experiment, Takahashi et al.^[7] solidified

hypermonotectic aluminum - 30 wt pct indium alloys subjected to ultrasonic energy with similar results. The above experiments examined metallic, miscibility gap systems from which microstructural development must be inferred after solidification is complete.

The solidification process can be directly observed and recorded by using transparent materials which simulate freezing phenomena in metals and alloys, a technique that is well established and accepted. With this background, the work presented here will focus on recent results obtained from such transparent systems. Specifically, a directional solidification furnace has been constructed such that the temperature range encompassing the solid, - liquid, interface and miscibility gap region of selected hypermonotectic composition, succinonitrile-glycerol "alloys" can be directly observed. Here the processing parameters are controlled and repeatable during, or without, application of ultrasonic energy. Secondly, low-melting point metals (e.g., tin and indium) have been ultrasonically dispersed in higher melting point salts with the intent of shedding light on the processing parameters, particle size, shape, and distribution. Support from NASA grants NAG8-1231 and NCC8-66 is gratefully acknowledged.

References

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